Opportunities in Nuclear Science
The 2002 NSAC Long Range Plan

HEPAP Meeting
November 7, 2002

James Symons
Chair, DOE/NSF Nuclear Science Advisory Committee

Charge

"identify **the most compelling scientific opportunities** to be addressed in the next decade"

"identify the **resources** that will be needed to address them"

"articulate the **priorities** of the identified scientific opportunities"

"indicate what funding levels would be required (including construction of new facilities) to maintain a **world-leadership position in nuclear physics research"**

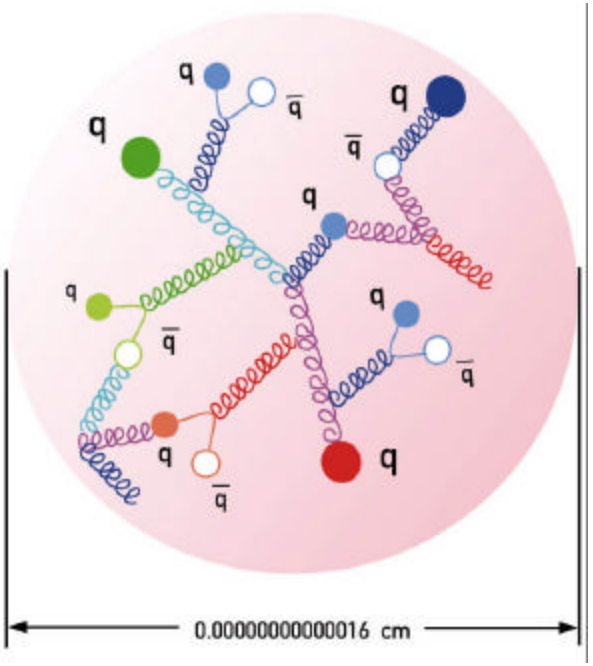
"determine the impacts and priorities if the funding available provides **constant level of effort** into the out years"

In the 1996 LRP, NSAC recommended construction of a "next generation ISOL-type facility" to be "constructed when RHIC construction is substantially complete." The plan should evaluate the scientific potential of the proposed Rare Isotope Accelerator and any other new proposed facilities in the broad context of the most compelling scientific questions, as well as the availability of existing and planned facilities, and establish priorities for new construction.

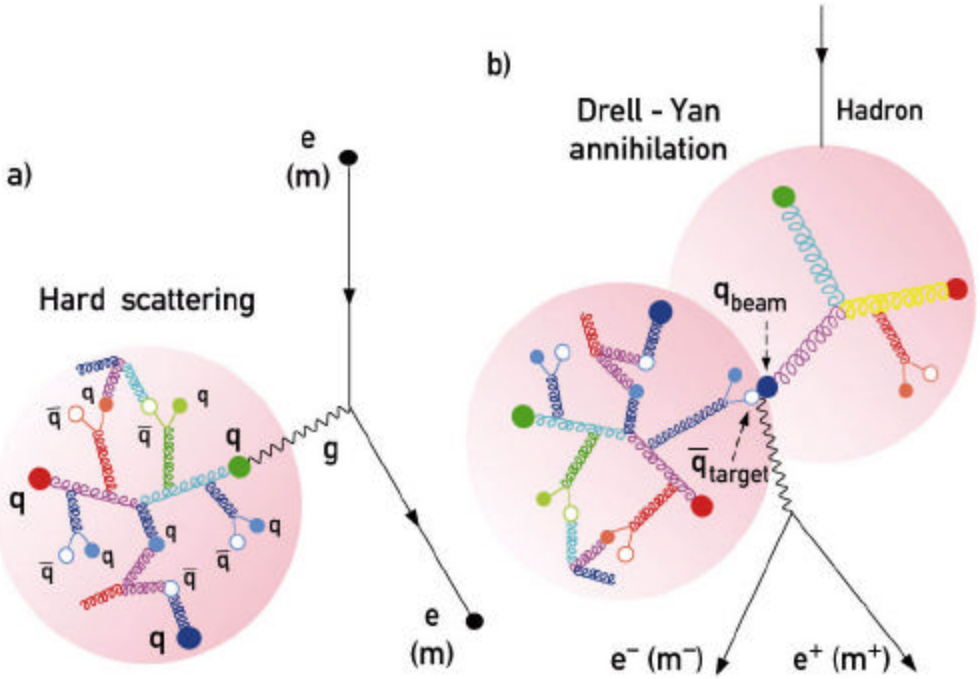
Scientific Questions

- ***What is the structure of the nucleon?***
- ***What is the structure of nucleonic matter?***
- ***What are the properties of hot nuclear matter?***
- ***What is the nuclear microphysics of the universe?***
- ***What is to be the new standard model?***

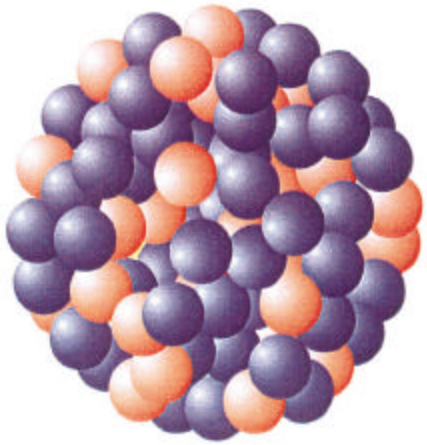
Nucleon Structure



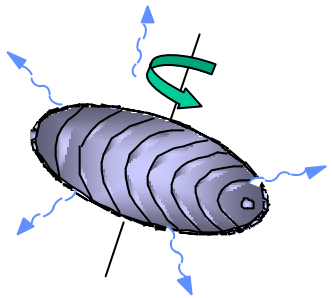
CEBAF
(MIT/Bates, DESY, FNAL, SLAC)
Precision electromagnetic probes
RHIC SPIN



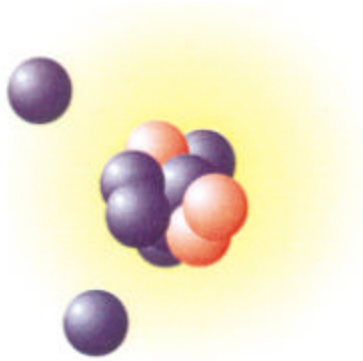
^{208}Pb



≈ 0.00000000000145 cm



^{11}Li



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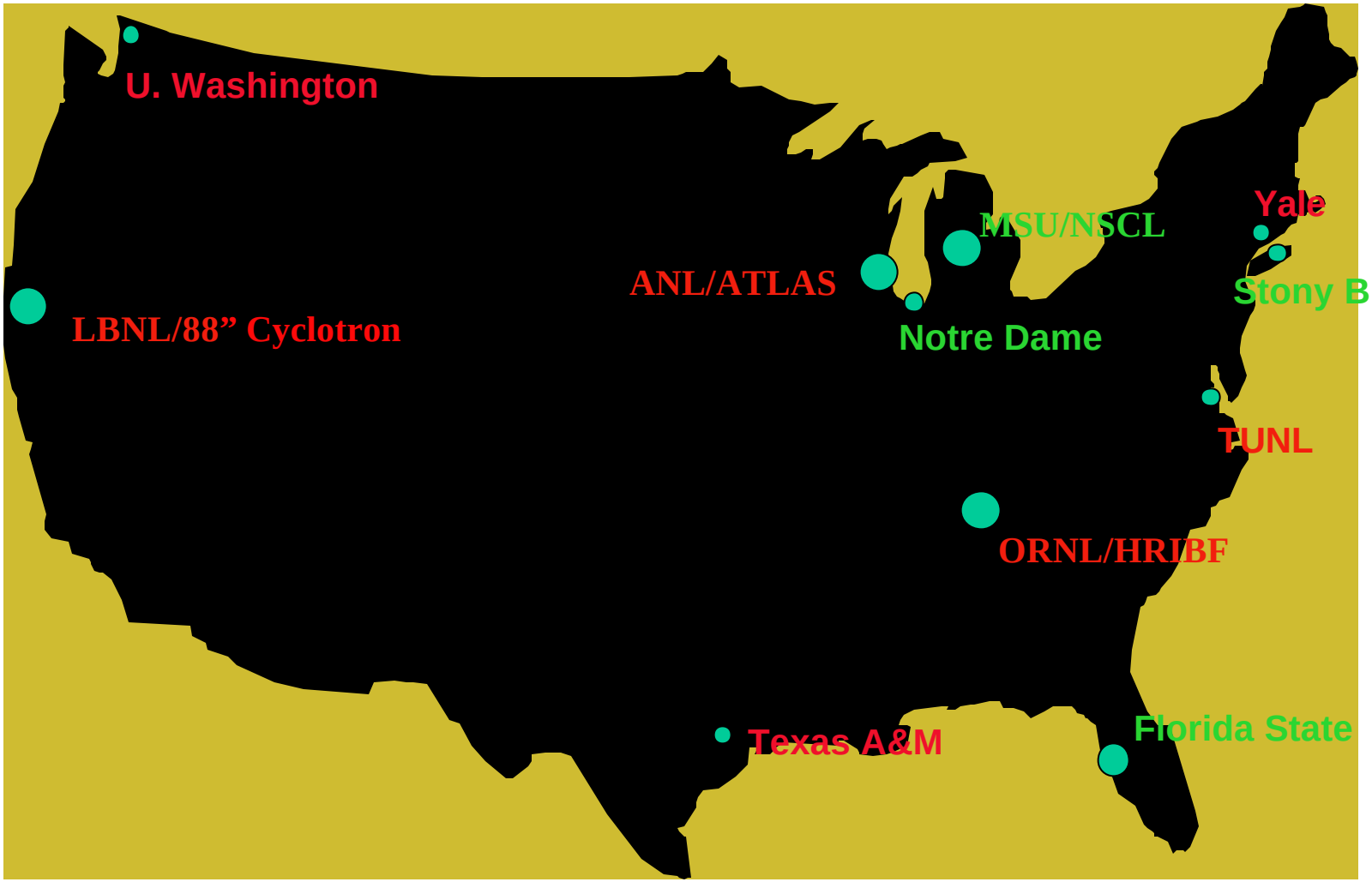
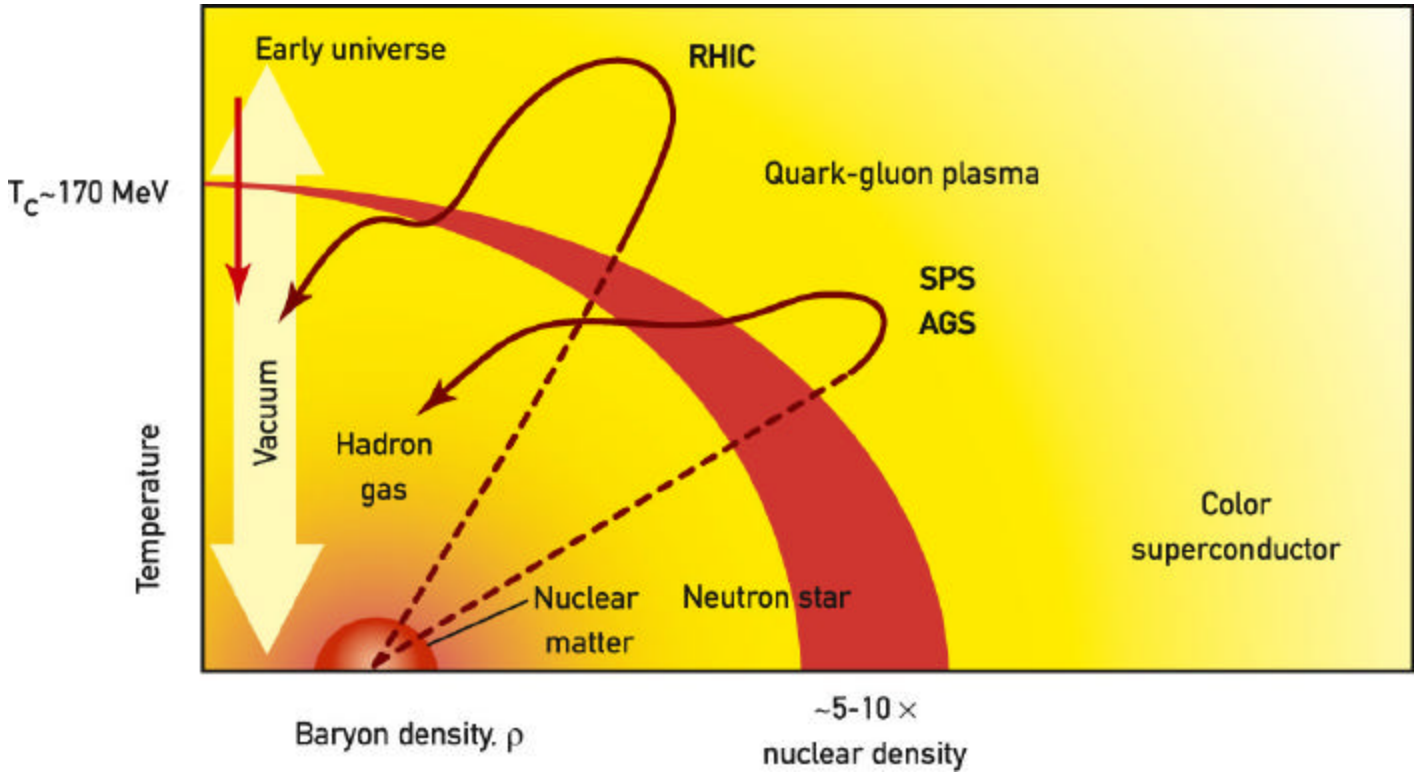
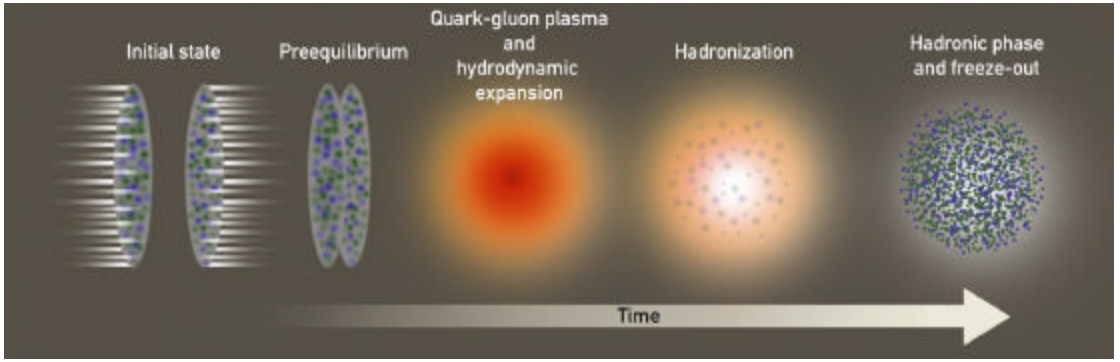
Experimental Facilities - Nuclear Structure



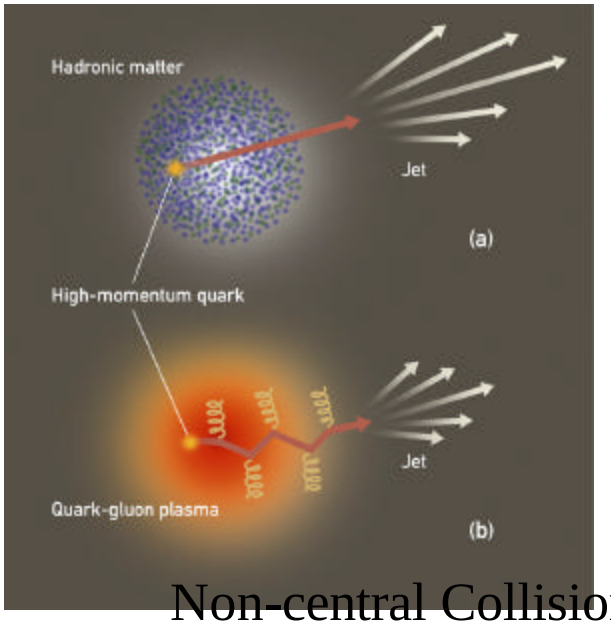
Another way to learn about QCD and Nuclear Matter



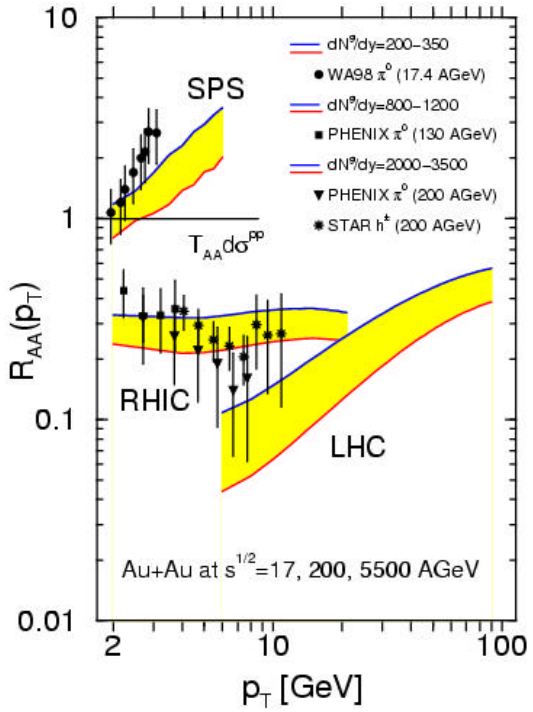
RHIC: takes advantage of short mean free path to create locally hot and dense nuclear matter.

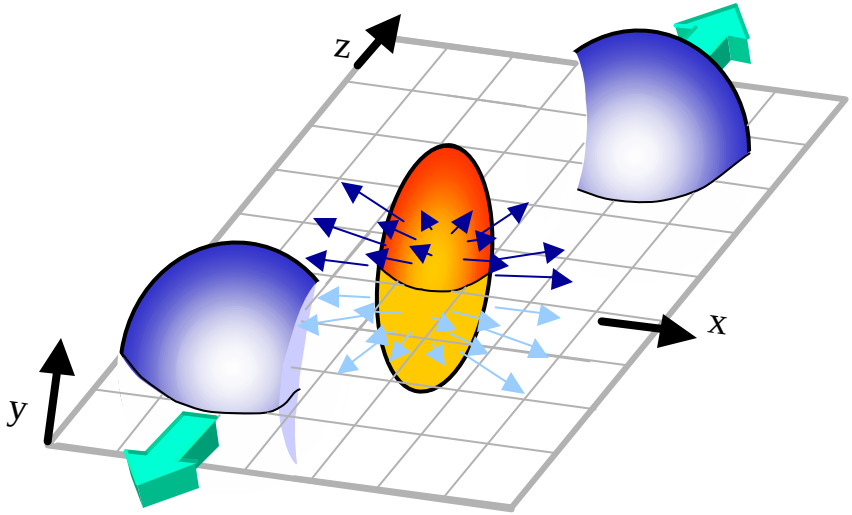


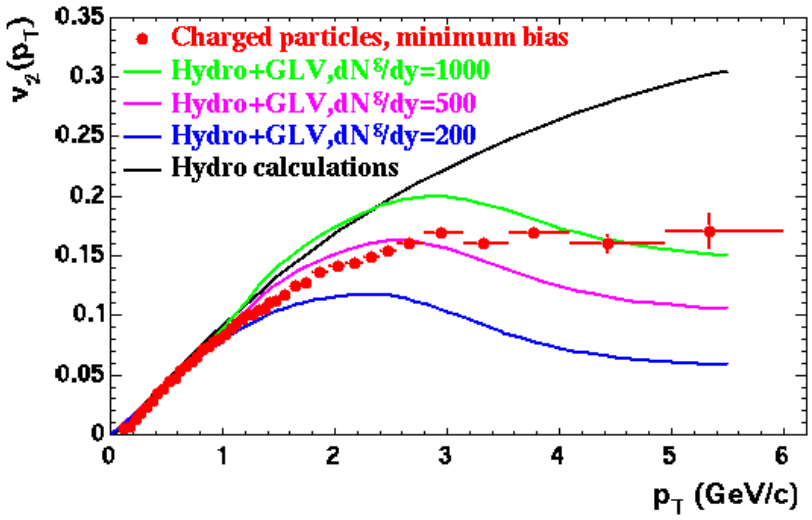
Recent Accomplishments - RHIC



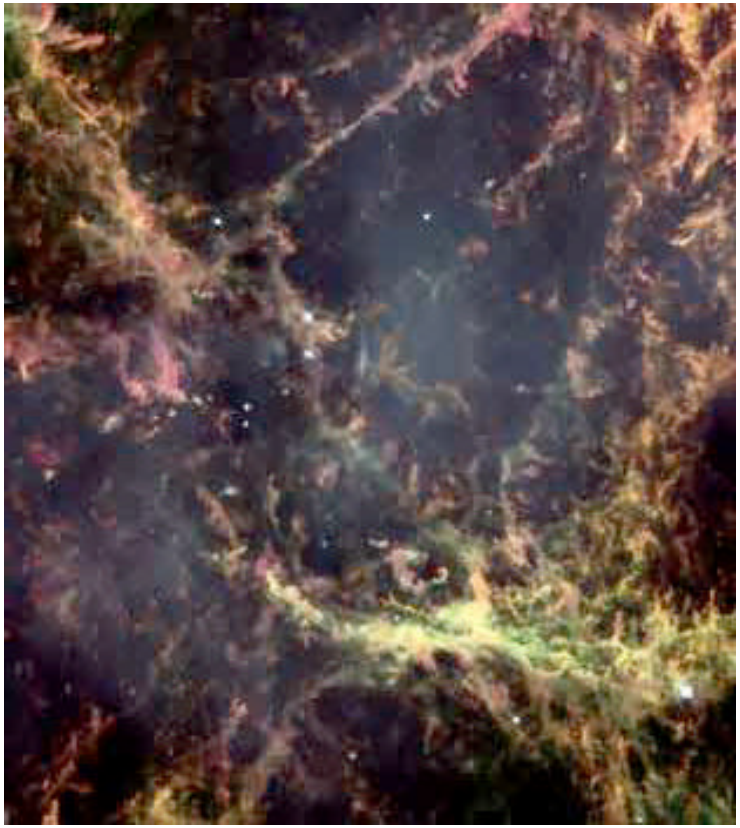
Non-central Collisions





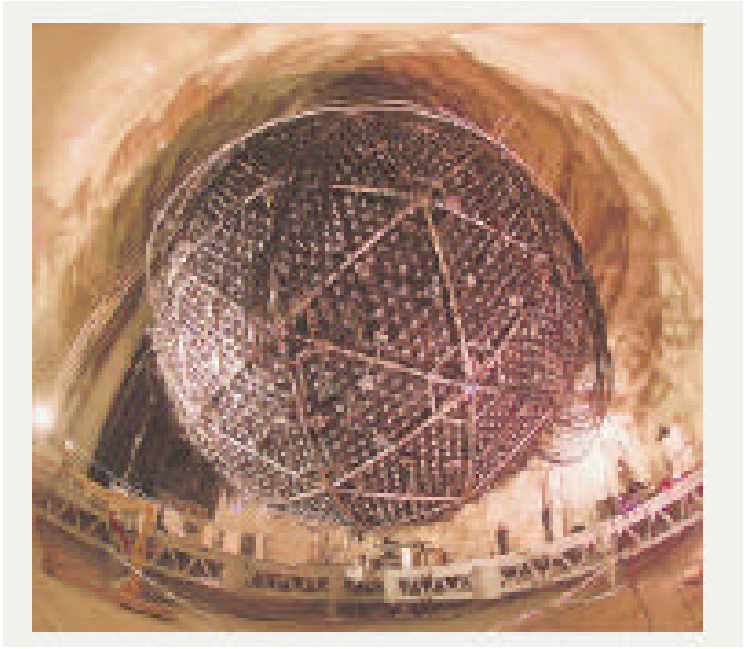


Nuclear Microphysics of the universe



Crab Nebula - contains a nucleus 10km in diameter

New Standard Model



The Sudbury Neutrino Observatory

Canadian / US / UK Collaboration

1000 Tons of D2O

7000 Tons of Ultrapure Water

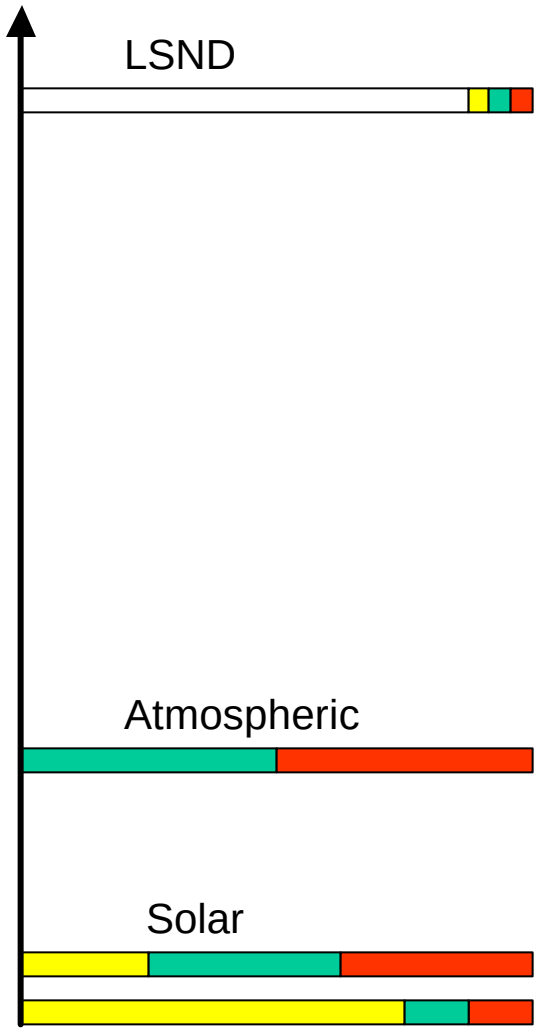
2000m below ground

Measures Charged and Neutral Current Neutrino Interactions

Super Kamiokande provided first evidence that neutrinos oscillate

SNO has definitively shown that neutrinos change state between creation in sun and arrival in Canada! Only 1/3 arrive in original form

A viable mass spectrum



	Mass (eV)	Percentages e	mu	tau
$?_s$	~1	~5	~2	~2
$?_3$	0.05		50	50
$?_2$	0.007	28	36	36
$?_1$	=0	72	13	13

Interdisciplinary Aspects

Connections to related fields:

High Energy Physics (QCD, Neutrino Physics)

Astrophysics (Neutron Stars, Supernovae)

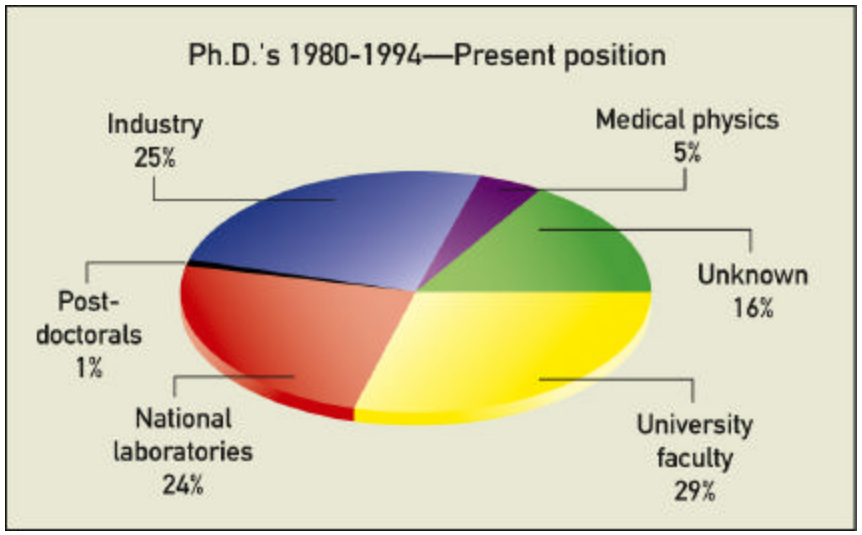
Theoretical Foundations:

Many Body Physics

Technical Foundations:

Computational Physics

Education and Outreach



Graduate education: Preparation for Leadership

Undergraduate education: Introduction to the Excitement of Research

Outreach

Expanding Opportunities to a Diverse Population

Former Yale graduate student Dan Bardayan, working on a recoil spectrometer and silicon detector array at Oak Ridge.

Sarah Phillips and Allyn Powell, graduate students at the College of William and Mary, helping with the construction of one octant of the scintillator detector for the G0 apparatus at Jefferson Lab.

International Collaboration and Cooperation

Nuclear science has become a world wide effort

Shared facilities, shared planning, complementary capabilities

US participation in experiments overseas

Process

One Working Group

- Science Education and Outreach
- Astrophysics Neutrinos and Symmetries
- Electromagnetic & Hadronic Physics
- Nuclear Structure and Astrophysics
- High Energy Nuclear Physics

5 Whitepapers




4 Town Meetings organized by APS/DNP

18 Institutional Summaries

22 Topical White Papers

www.star.bnl.gov/nsac


OVERVIEW OF
OPPORTUNITIES IN NUCLEAR SCIENCE
A Long-Range Plan for the Next Decade
June 2002
The DOE/NSF Nuclear Science Advisory Committee
U.S. Department of Energy • Office of Science • Division of Nuclear Physics
National Science Foundation • Division of Physics • Nuclear Physics Program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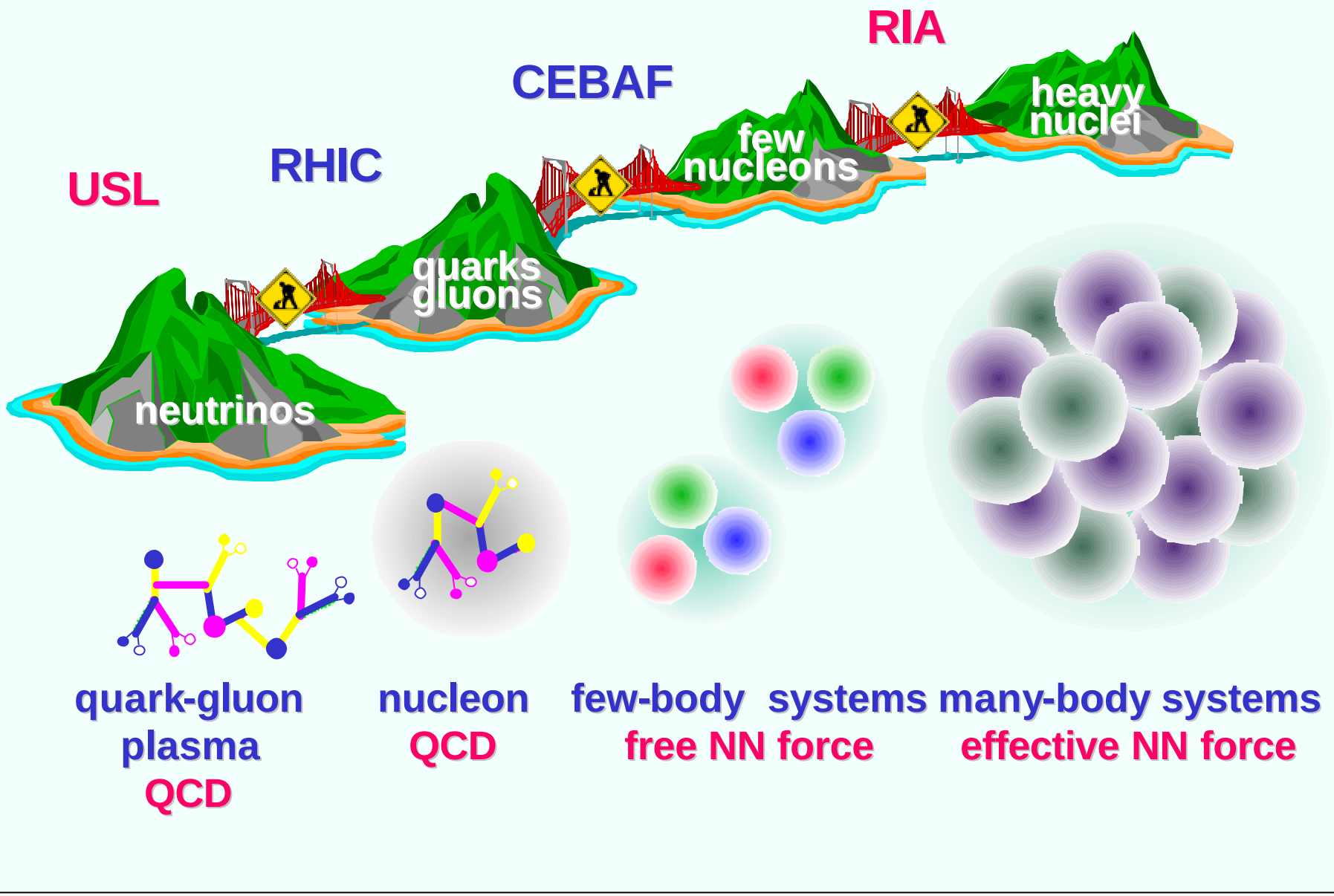
What was on table

Initiatives/Opportunities from Community

<$100M	<$200M	Decadal
EIC/RHIC R&D	JLab 12 GeV Upgrade	RIA
Computing Initiative for Theory	RHIC II	
Gamma Ray Tracking	Underground Laboratory	
Neutrons (SNS and Los Alamos)	(EIC)	
Orland		


RIA
CEBAF
RHIC
USL
heavy nuclei
few nucleons
quarks gluons
neutrinos
quark-gluon plasma QCD
nucleon QCD
few-body systems free NN force
many-body systems effective NN force

Road map

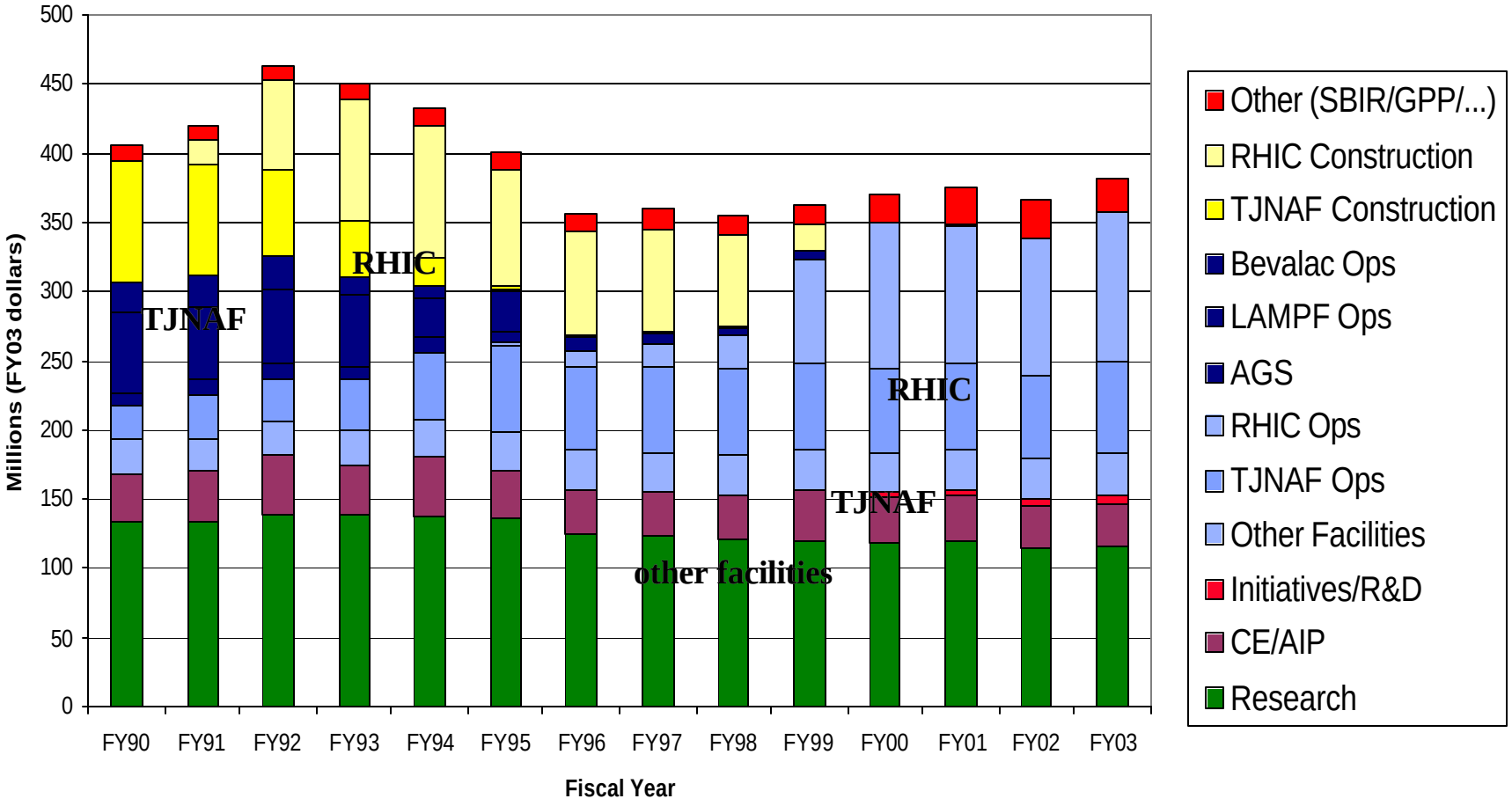
First Recommendation

Recent investments by the United States in new and upgraded facilities have positioned the Nation to continue its world-leadership role in nuclear science. The highest priority of the nuclear science community is to exploit the extraordinary opportunities for scientific discoveries made possible by these investments. Increased funding for research and facility operations is essential to realize these opportunities.

Specifically, it is imperative to :

- Increase support for facility operations – especially our unique new facilities RHIC, CEBAF, and NSCL – which will greatly enhance the impact of the nation's nuclear science program.
- Increase investment in university research and infrastructure, which will both enhance scientific output and educate additional young scientists vital to meeting national needs.
- Significantly increase funding for nuclear theory, which is essential for developing the full potential of the scientific program.

DOE Nuclear Physics Funding History



Issue: Facility Support

Facility	FY01 operations (weeks)	Efficient operations (weeks)	No. of active users
Electron accelerators			1000
CEBAF	33	40	
MIT-Bates	26	35	
Relativistic heavy-ion collider			1000
RHIC	14	30	
Light- and heavy-ion facilities			1000
NSCL	Under Construction	40	
ATLAS	39	43	
88-Inch Cyclotron	35	42	
HRIBF	20	37	
IUCF	26	39	

Facilities have been operating at 15-45% below effective levels.

15% Funding increase over FY01 level will address address

FY03 Administration request *significantly* improves the situation

Issue: Nuclear Theory

- ***Many current problems require intensive theoretical work,***
- ***Impact of large scale computing is pervasive(Lattice qcd, supernova modeling, nuclear structure)***
- ***New positions in nuclear theory at universities***
- ***Number of theorists has declined relative to experimentalists***

- ***Not just a $$ or numbers problem: structure of subfield should be examined by panel of senior and junior theorists, experimentalists.***
  - **Where will increases in support be most effective? Theory Fellows, etc.**

What next?

- ***Long term success of field will rely on continued new investment in areas of greatest scientific interest.***
- ***Issue of Balance:***
  - **Operating support**
  - **Major new facilities**
  - **Smaller initiatives and upgrades**
- ***Field cannot stand still even under strictest budget conditions***

Second Recommendation

The Rare Isotope Accelerator (RIA) is our highest priority for major new construction. RIA will be the world-leading facility for research in nuclear structure and nuclear astrophysics.

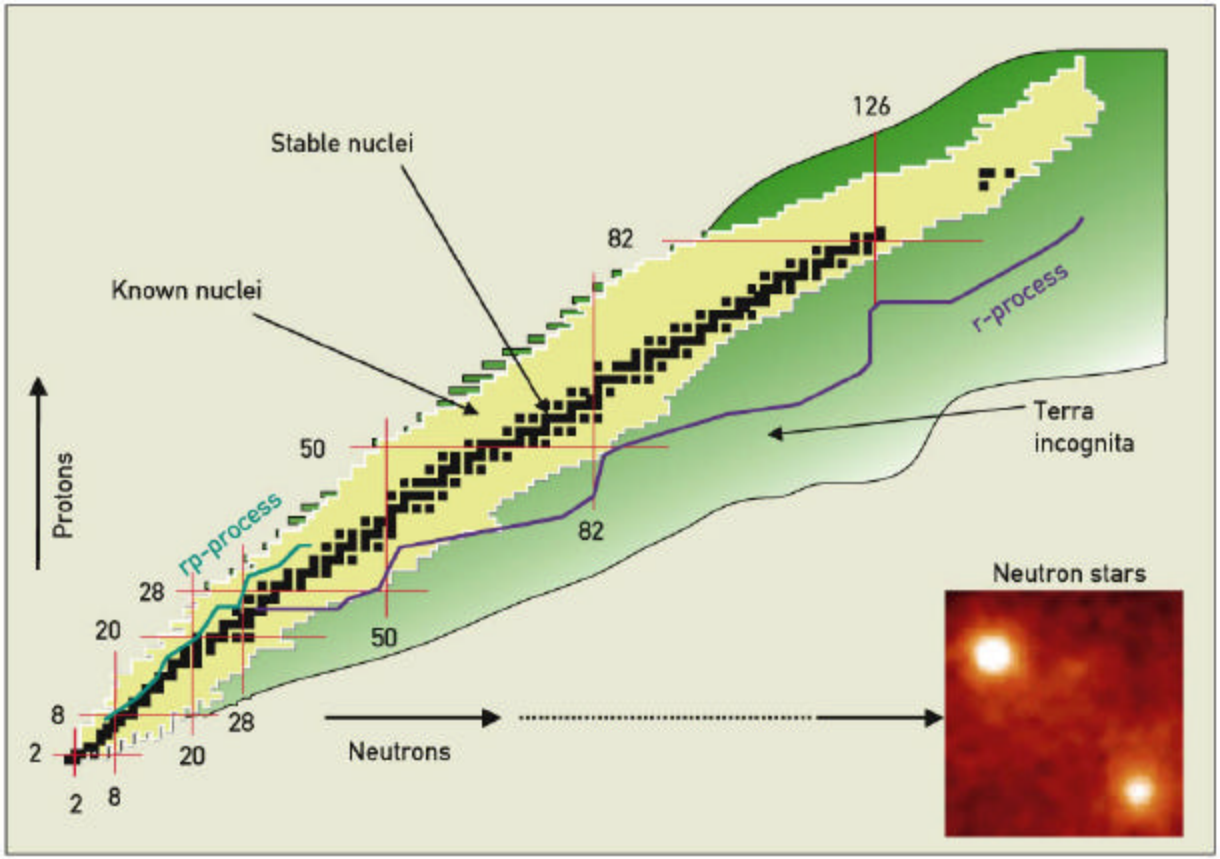
The exciting new scientific opportunities offered by research with rare isotopes are compelling. RIA is required to exploit these opportunities and to ensure world leadership in these areas of nuclear science.

RIA will require significant funding above the nuclear physics base. This is essential so that our international leadership positions at CEBAF and at RHIC be maintained.

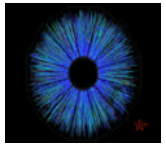
RIA Goals

- ***Investigations into the nature of nucleonic matter***
- ***Understanding the origin of the elements and energy generation in stars***
- ***Tests of symmetries and of fundamental conservation laws***

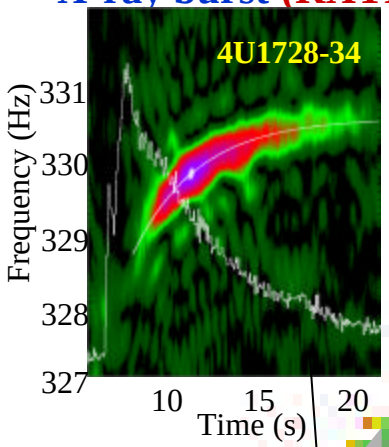
Where we want to go:



Where RIA will take us



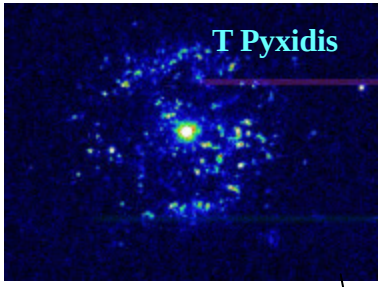
X-ray burst (RXTE)



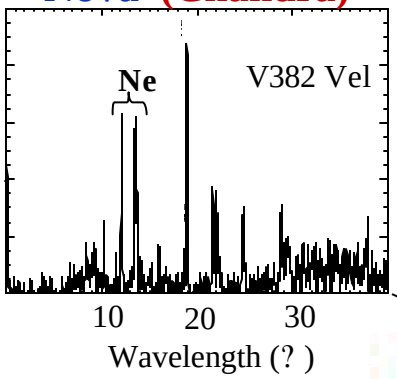
RIA intensities (nuc/s)

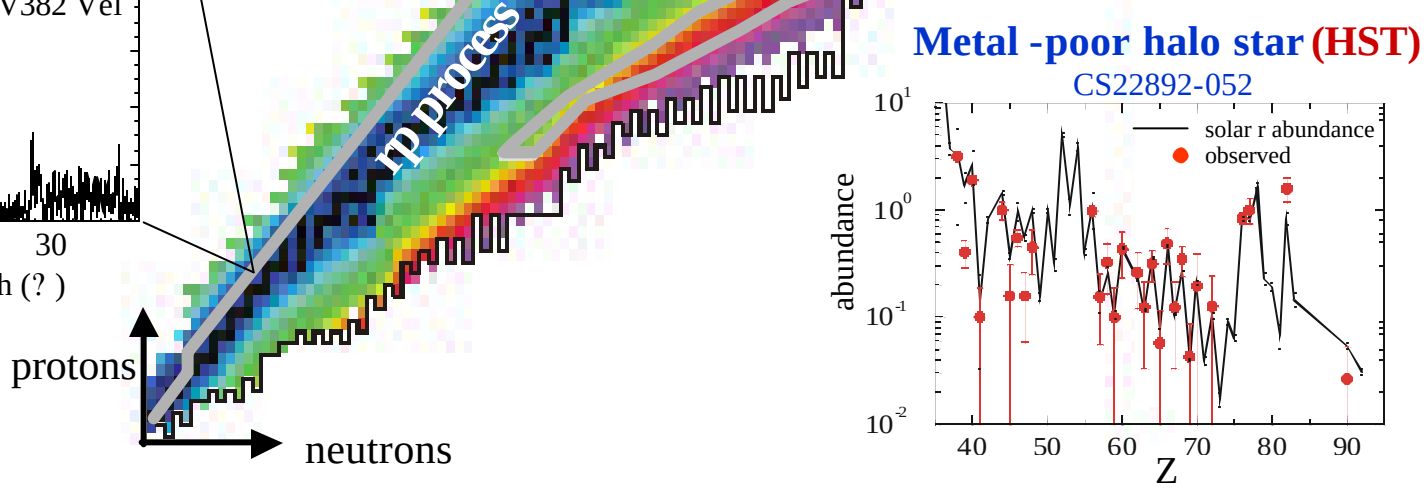
$>10^{12}$ 10^{2}
10^{10} 10^{-2}
10^{6} 10^{-6}

Nova (HST)



Nova (Chandra)



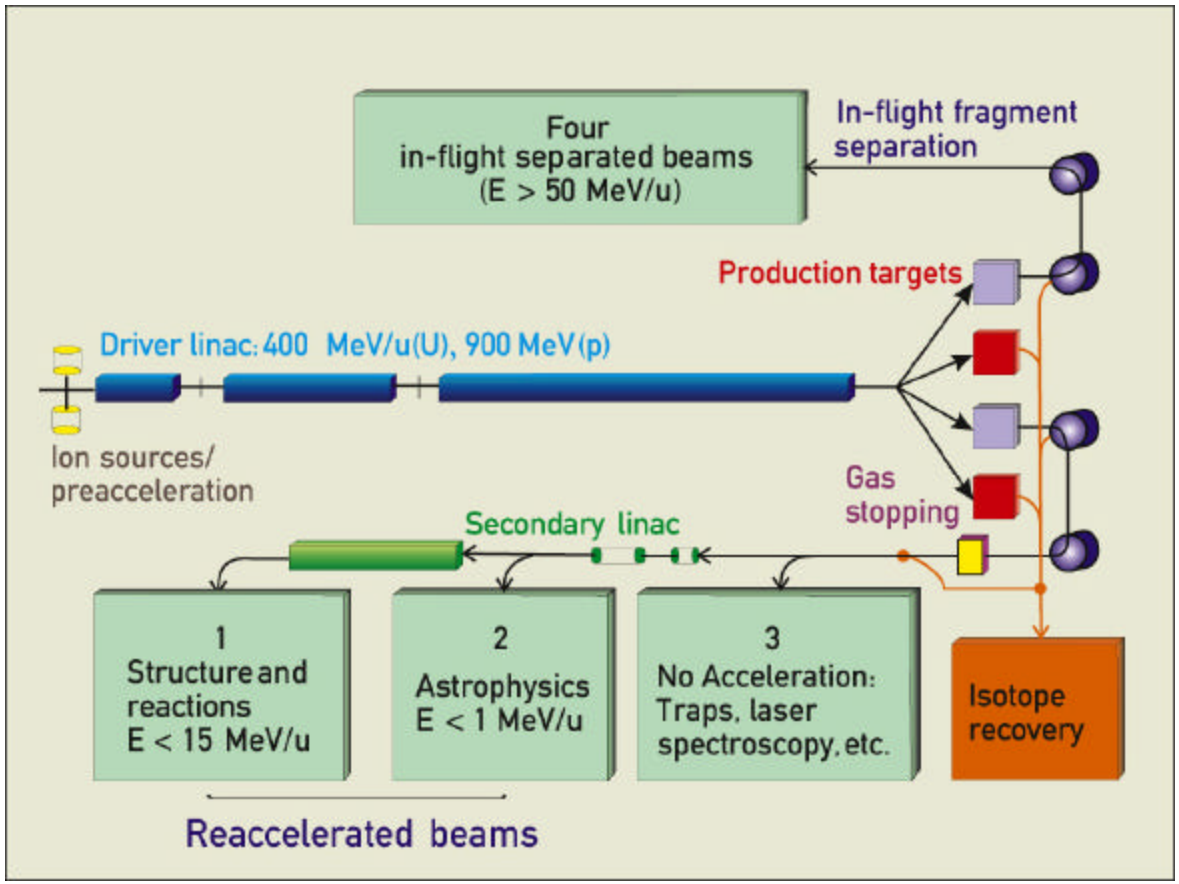


Metal -poor halo star (HST)

CS22892-052

RIA Concept

On the world scene, RIA will offer the greatest variety and highest intensities of any rare isotope accelerator

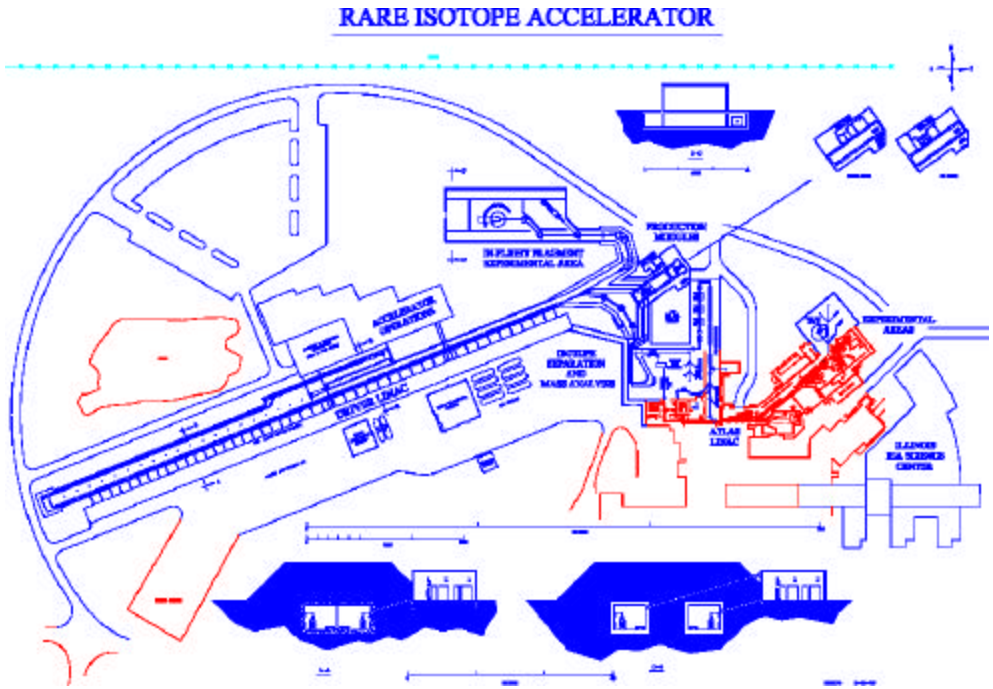


Siting of RIA at National Laboratory and University Sites is under consideration.

Common technical solution developed by NSAC sub-committee

Coordinated R&D Program

Where would it be sited?



Third Recommendation

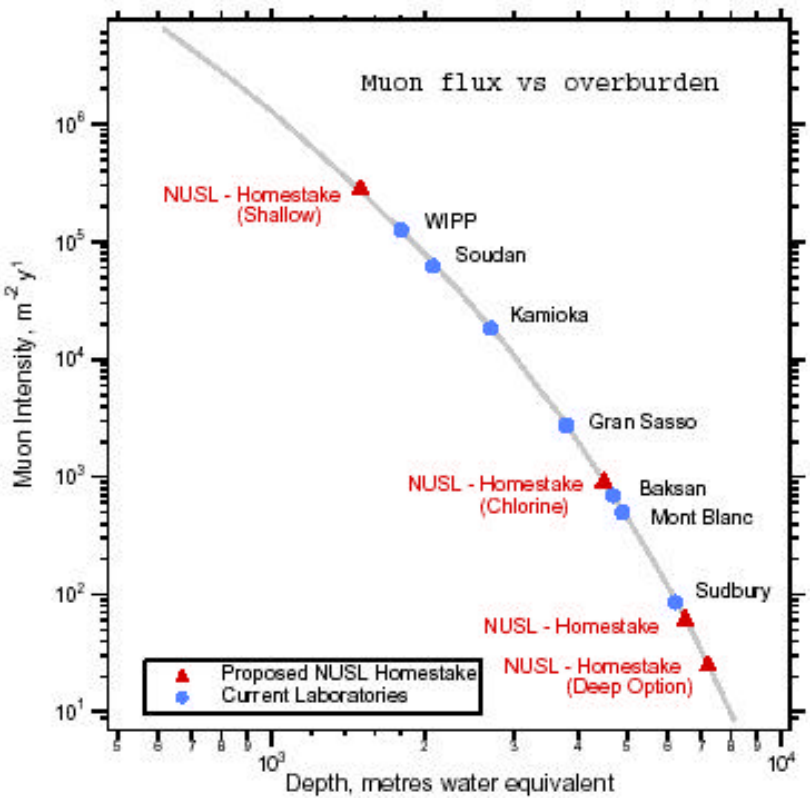
We strongly recommend immediate construction of the world's deepest underground science laboratory. This laboratory will provide a compelling opportunity for nuclear scientists to explore fundamental questions in neutrino physics and astrophysics.

Recent evidence for neutrino mass has led to new insights into the fundamental nature of matter and energy. Future discoveries about the properties of neutrinos will have significant implications for our understanding of the structure of the universe. An outstanding new opportunity to create the world's deepest underground laboratory has emerged. This facility will position the U.S. nuclear science community to lead the next generation of solar neutrino and double beta-decay experiments.

NUSEL Scientific Opportunities

- ***Next generation solar neutrino experiment***
  - **Focus on low energy neutrinos, flux precisely constrained by solar luminosity**
- ***Double beta decay***
  - **Neutrino mass scale**
- ***Nuclear Astrophysics***
  - **Accelerator underground for cross section measurements**
- ***Other opportunities***
  - **Proton Decay / Long-baseline neutrino oscillations**
  - **Earth Sciences**
  - **Geomicrobiology**

NUSEL - Background Suppression



Depth is a crucial factor for many underground experiments: e.g. next generation solar neutrino and double beta decay measurements.

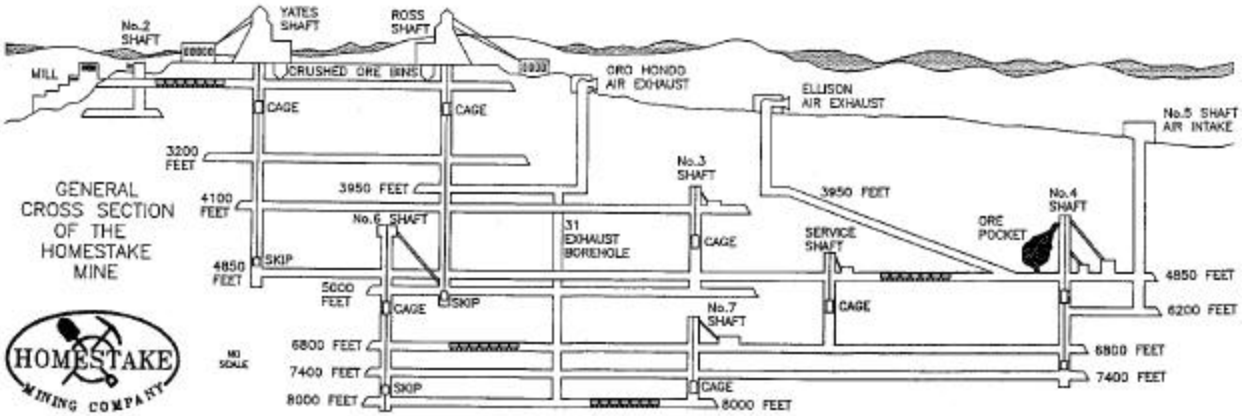
NUSEL can provide both deep and shallow laboratories

NUSEL Proposal: Homestake mine

Opportunity has arisen because of cessation of operations at Homestake.

Proposal under consideration by NSF

Principal Investigators from HEP and NP

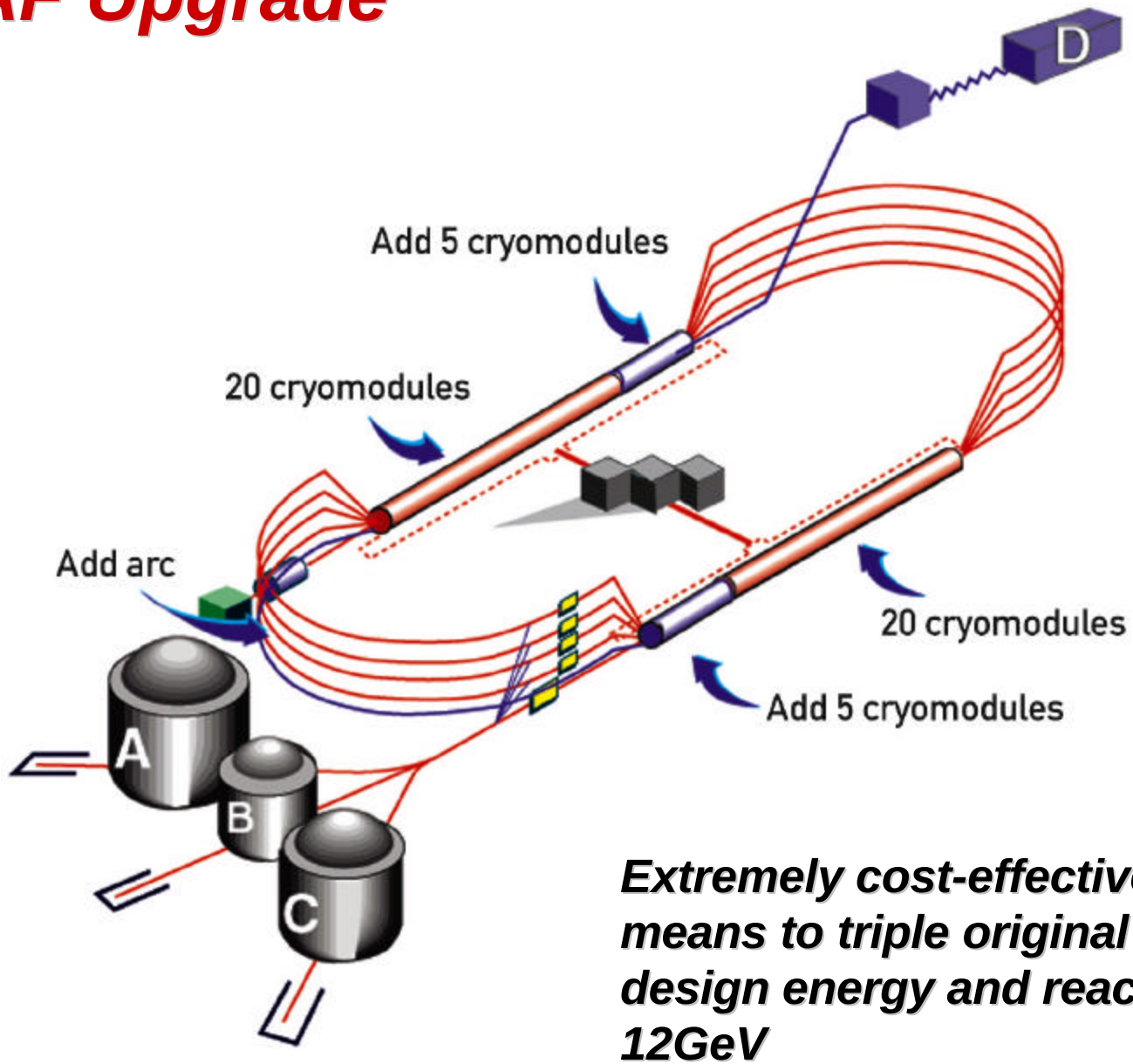


Fourth Recommendation

We strongly recommend the upgrade of CEBAF at Jefferson Laboratory to 12 GeV as soon as possible.

The 12 GeV upgrade of the unique CEBAF facility is critical for our continued leadership in the experimental study of hadronic matter. This upgrade will provide new insights into the structure of the nucleon, the transition between the hadronic and quark/gluon description of matter, and the nature of quark confinement.

CEBAF Upgrade



Extremely cost-effective means to triple original design energy and reach 12GeV

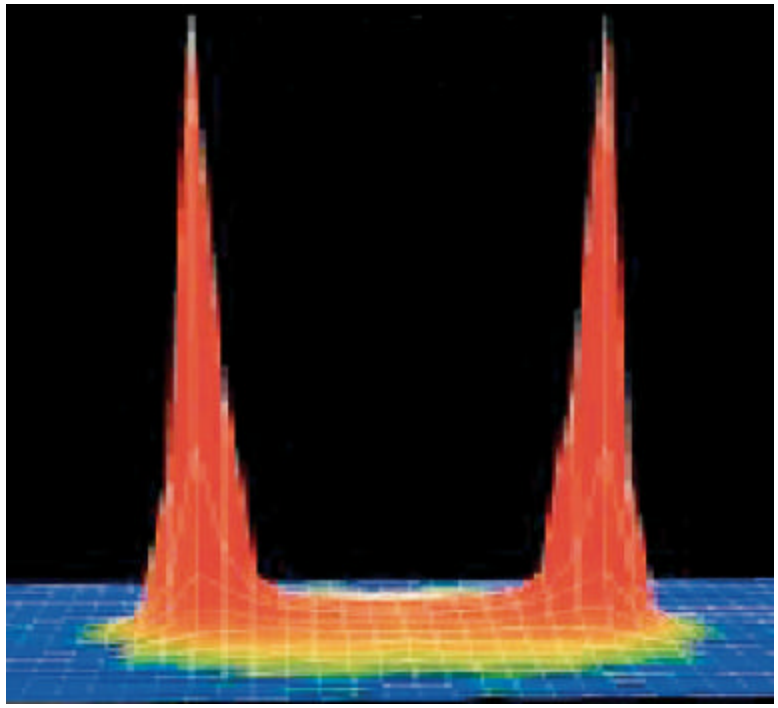
Opportunities with the CEBAF Upgrade

Exotic mesons

- Hall D, 12 GeV Photons

Exclusive reactions in 'valence quark' domain

- Generalized parton distributions



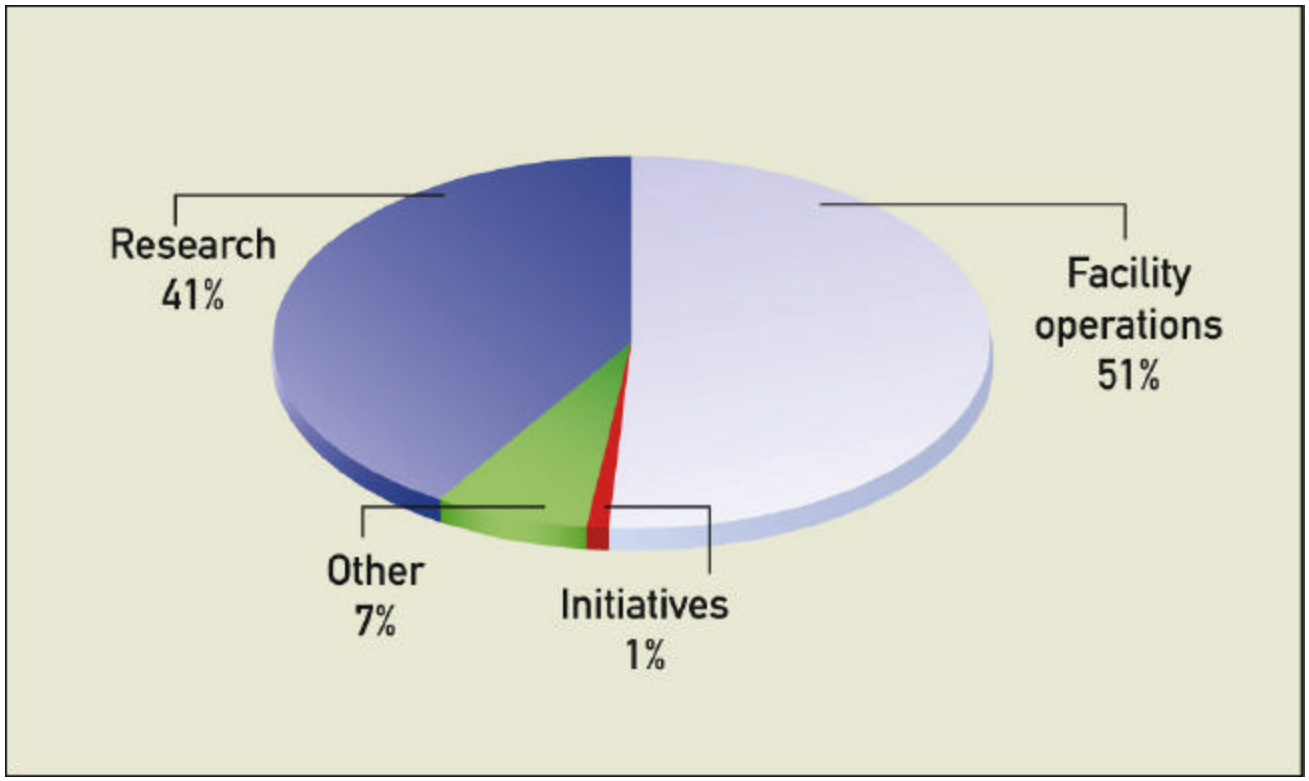
Strings on the Lattice

Other Initiatives

- ***RHIC II***
  - **Luminosity upgrade for the RHIC heavy ion program**
- ***EIC***
  - **Electron-ion collider; could utilize RHIC ring**
- ***Neutron Initiative***
  - **Exploiting cold and ultra-cold neutrons at SNS, LANSCE**
- ***4p Gamma-Ray Tracking Array***
- ***Large Scale Computing***
  - **Lattice QCD, Supernova Calculations, SciDAC Connection**
- ***Orland***
  - **Use copious neutrino flux from SNS**

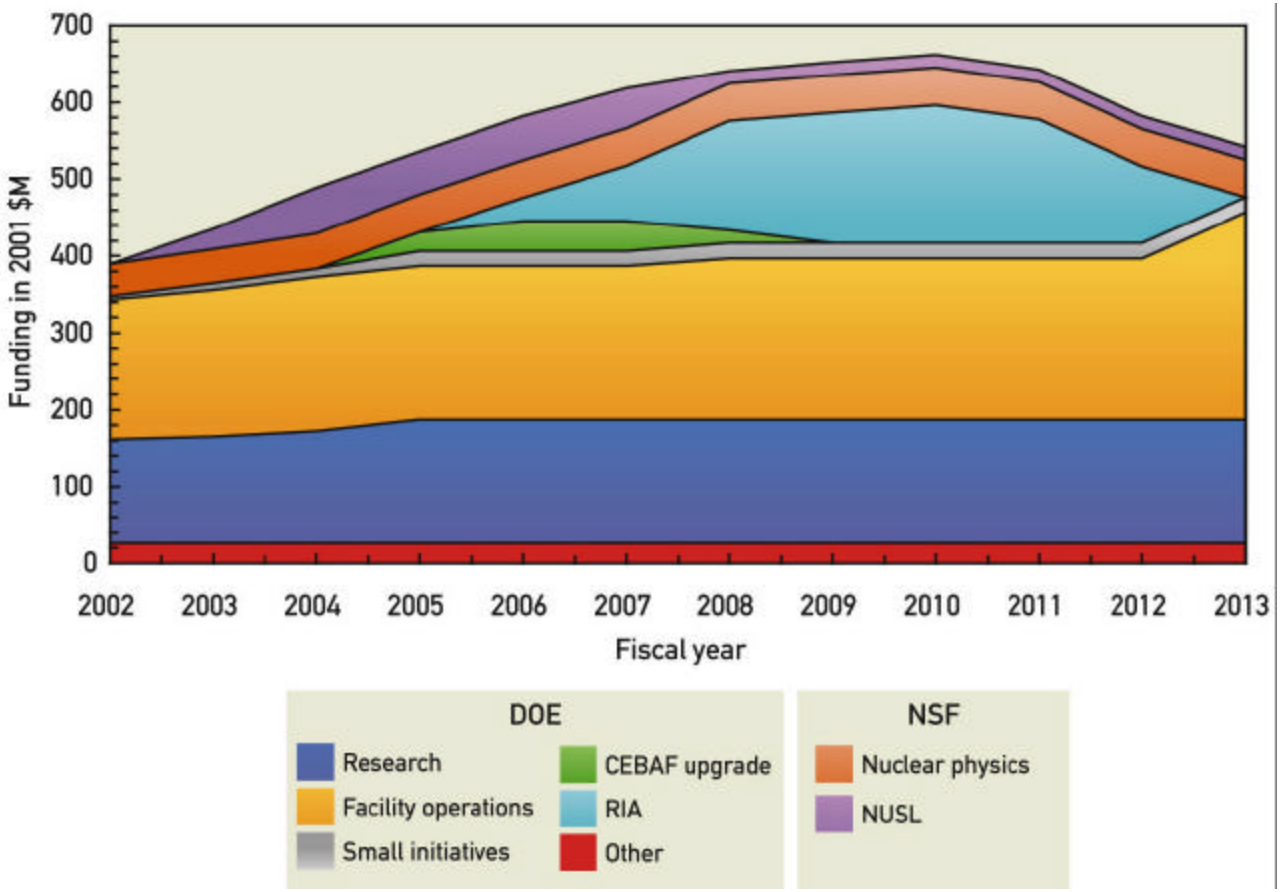
Resources

DOE Funding dominated by facility operations



Because RHIC and CEBAF are new facilities, incremental funding is necessary for a large facility such as RIA

A Scenario



Features:

- ***15% increase for operations at DOE and NSF facilities***
- ***RIA, JLAB upgrade and NUSL construction and operations on top of base***
- ***Allocation of some funds to smaller initiatives***

Where do things stand?

- ***Operating Budgets***
  - **Operating reviews at RHIC, JLAB and ORNL**
  - **FY03 Administration Request and Congressional Mark-ups very encouraging: +6.1% House, +7.5% in Senate**
  - **Half way towards goal set by LRP**
- ***RIA and JLAB Upgrade***
  - **R&D Continuing**
  - **CD0 Decisions on hold, pending prioritization within Office of Science**
- ***NUSEL***
  - **Scientific Case Strengthened**
  - **Ness2002 Workshop**
  - **NRC Panel report expected soon**
- ***NP Program Moving Ahead with Smaller Initiatives***
  - **GRETA, Neutron Beam Line, RHIC R&D, Detector Upgrades, Computing Initiatives(SCIDAC)**

Summary

- ***Scientifically: "the best of times"***
- ***Nuclear Physics looking forward to an exciting decade***
- ***Wealth of opportunities within the Office of Science***
  - **Importance of physical sciences is increasingly well understood**
  - **Our fields have much to gain by working together**